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REVEGETATION STUDY OF ADOBE DAM PHOENIX ARIZONA TASK 2 1/1

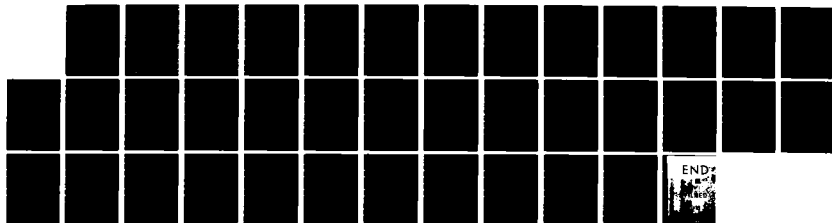
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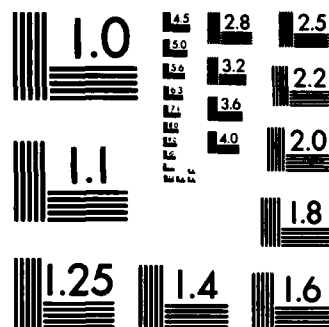
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Task No. 3 "Revegetation Methods for Arid Areas".

This report presents a comparison of methods of revegetation used by the Arizona Department of Transportation, mining companies in the Phoenix area, and the Desert Botanical Garden.

Task No. 4 "Site Characteristics."

This report describes the site characteristics of the Adobe Dam Study Area.

Task No. 5 & 7 Seeding Success on Topsoiled and Hard Topsoiled Slopes at Adobe Dam".

This report presents statistical analysis of the relative success of several seeding methods used at the Adobe Dam site.

Task No. 6 "Evaluation of three watering and Molding Techniques on Transplanted Trees at Adobe Dam."

This report evaluated the relative success of alternative watering regimes and types of water used on transplanted trees of Adobe Dam.

Task 8. "Final Evaluation and Recommendation on Reclamation at Adobe Dam."

This report summarizes the findings of Tasks 2 through 7 and presents a series of specific recommendations for achieving success in arid lands revegetation projects.

Report

To

The U.S. Army Corps of Engineers
Los Angeles District

A Review and Analysis
of Three Revegetation Projects
by the U.S. Army Corps of Engineers
Task #2

REVISED

by

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September 29, 1982

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INTRODUCTION

In Maricopa County, the Army Corps of Engineers has completed a series of flood control projects. The problem of revegetating those areas disturbed by construction usually follows completion of each project. A number of approaches to this problem have been taken by the Corps with various degrees of success. As future flood control projects are planned for Maricopa County and the Arizona desert area, there is a need to review past projects. Three Corps' projects: Dreamy Draw Dam, Indian Bend Wash and Cave Buttes Dam have been examined in terms of the revegetation techniques utilized and the overall effectiveness of these measures in re-establishing vegetation. In each of these projects, seeding was the primary method of re-establishing vegetation. A successful seeding operation is dependent upon three major factors: preparing the seedbed, selecting suitable plant species, and properly planting the seed. The individual projects were reviewed considering these factors and the results of in-field vegetation sampling are presented in order to demonstrate overall seeding effectiveness. Based on these reviews and observations, a comprehensive conclusion of the three sites is presented with corresponding recommendations for revegetation projects in Maricopa County.

Dreamy Draw Dam

Site Conditions

This project has unique site characteristics in relation to the other projects studied in this report. Located adjacent to the Phoenix Mountain Preserve, this particular site has very shallow, rocky soils. Also, because the dam is situated within a draw, the area has a slightly higher annual moisture input than the surrounding desert areas.

Seedbed Preparation

Three locations within the project area were seeded. At these locations, topsoil was applied to an average depth of six inches. Specifications call for all surface irregularities in the topsoil to be leveled to prevent depressions and all debris (rocks, stones, etc.) to be removed. A minimal amount of tillage was performed to alleviate compaction caused by heavy machine traffic. 1000 lbs./acre of mulch and 400 lbs./acre of 10-20-10 fertilizer were applied at the time of seeding. The final seedbed consisted of a smooth layer of topsoil underlain by the rocky subsoil typical of the area.

Plant Species Selection

Eragrostis Lehmanniana (Lehman's lovegrass), a warm season, short lived, perennial bunch grass, was selected for use at Dreamy Draw. This grass, although not deeply rooted, is fairly drought tolerant and easy to establish on freshly prepared seedbeds. It does best in sandy textured soils at elevations ranging from 3,500 to 5,000 feet, with an annual precipitation of 11" - 16". Spreading rapidly by seed when established, this grass is commonly used in Southwest revegetation. The recommended seeding rate (Jordon 1981) is 1 lb. Pure Live Seed/acre (PLS/acre) for broadcast seeding (see Appendix). At Dreamy Draw dam, approximately 2.5 lbs. PLS/acre were applied.

Lolium multiflorum, an annual rye grass, was the only other species used at Dreamy Draw. It is not tolerant of dry soil conditions and should be kept moist for best growth (Duffield and Jones 1981). This introduced species is typically used for winter lawns in Phoenix, although some use for seasonal erosion control in the Northeastern United States has been reported (Wright, Perry and Blaser 1978). The recommended seeding rate for the latter use is 30 lbs. PLS/acre; the Corps seeded approximately 34 lbs.PLS/acre at Dreamy Draw.

Planting Procedures

The exact seeding dates for Dreamy Draw Dam are unknown. However, because of the moisture and temperature requirements of the species selected, seeding at any-time other than early fall is precluded. A hydroseeder with a built-in agitating system was used to apply a homogeneous slurry of water, seed, mulch and fertilizer to the seedbed. Nothing further was done to ensure proper seed coverage.

Methods of Vegetational Sampling

Vegetation sampling was conducted on two of the three seeded sites within the Dreamy Draw project area. A modification of the canopy-coverage vegetative sampling technique developed by Daubenmire (1959) was utilized. This technique was designed for sampling herbaceous plants and shrubs less than 30 cm tall. Three line transects were placed in each area, and vegetation was sampled at 40 random locations along these transects using a 2dm x 5dm plot frame. Species falling within the frame were identified and counted. Frequency and diversity data were obtained in this manner.

Results of Vegetation Sampling

The results of vegetation sampling conducted upstream and downstream from the dam are presented in Table 1. Of the two seeded species, only Eragrostis Lehmanniana was found. It occurred in 12.50% of the sample plots upstream, and only 0.50% of the plots downstream, with densities of 2.50 plants/m² and 0.50 plants/m² respectively.

Dreamy Draw Conclusions

During field observations of the seeded areas, no evidence of the topsoiling operation was discovered. It is believed that because the topsoil did not adhere to the hard, smooth, underlying subsoils, it was eroded away. Subsoils should either be tilled to roughen the surface prior to topsoiling or mixed with the topsoil to prevent its loss. The preparation of a smooth seedbed, containing no depressions or cavities to capture seed or moisture should be avoided. Natural undulations create desirable microenvironments for establishing and maintaining vegetation. The high and low areas facilitate seed coverage, and improve moisture conditions by both reducing runoff velocity and increasing water infiltration. In fact, vegetation can often be established, without topsoiling, on roughened subsoils (Wright, Perry and Blaser 1978).

TABLE 1.— Mean frequency (%), and mean density (no./m²) for plants found 1) upstream and 2) downstream at Dreamy Draw dam in August 1981.

	Species	Upstream		Downstream		Common name
		Freq.	Density	Freq.	Density	
Grasses	<u>Aristida adscensionis</u>	5.00	0.50	7.50	0.75	Six-weeks three awn
	<u>Bromus rubens</u>	83.00	78.00	50.00	80.00	Red brome
	<u>Cynodon dactylon</u>	5.00	0.50	5.00	1.00	Bermuda grass
	<u>Eragrostis Lehmanniana</u>	12.50	2.30	5.00	0.50	Lehman's lovegrass
	<u>Schismus barbatus</u>	60.00	33.00	65.00	15.80	Mediterranean grass
	<u>Tridens pilosus</u>	27.00	30.60	20.00	8.75	Hairy tridens
Forbes	<u>Amsinckia intermedia</u>	5.00	0.50	--	--	Fiddle head
	<u>Centaurea melitensis</u>	12.50	1.50	--	--	Star thistle
	<u>Eriogonum densum</u>	33.00	3.80	43.00	8.30	Buckwheat
	<u>Erodium cicutarium</u>	18.00	2.00	20.00	2.80	Filary
	<u>Happlopappus larcinofolius</u>	2.50	0.30	--	--	Unknown
	<u>Plantago sp.</u>	33.00	5.50	88.00	63.50	Indian wheat
	<u>Stephanomeria exigua</u>	2.50	0.30	--	--	Wire lettuce
	<u>Ambrosia deltoidea</u>	7.50	0.75	2.50	0.30	Bursage
	<u>Atriplex Wrightii</u>	2.50	0.75	--	--	Saltbush
Shrubs	<u>Baccharis sarothroides</u>	7.50	1.00	--	--	Desert Broom
	<u>Encelia farinosa</u>	2.50	0.30	7.50	0.75	Creosote
	<u>Cercidium microphyllum</u>	7.50	0.75	2.50	0.25	Foothill Palo Verde
	<u>Prosopis juliflora</u>	2.50	0.25	--	--	Mesquite

The failure of Lolium multiflorum to establish in the seeded areas was probably due to its high moisture requirement. The continued occurrence of E. Lehmanniana, seven years after seeding, demonstrates that this grass has become established at Dreamy Draw Dam. The relatively low frequencies and densities, however, show that native grasses such as Schismus barbatus, Bromus rubens, and Tridena pilosus are better adapted to the area and, following their migration into the area, have developed a competitive advantage.

The occurrence of tree species Cerecidium microphyllum and Prosopis juliflora demonstrate that natural succession is well past the early stages in the seeded areas of Dreamy Draw Dam. The community found in the dam area can be judged healthy based on the variety of plant forms (grasses, forbes, shrubs, and trees) growing there. It is possible that the establishment of E. Lehmanniana in the seeded areas has promoted the successional development of the present plant community to some extent. It is believed, however, that the addition of other suitable species to the seed mix would have greatly enhanced both the successional and revegetation processes. The expense of seeds is only a small fraction of the entire seeding budget. Increasing the number of species seeded, especially with site compatible species such as those now found invading the site, would greatly improve the success of the seeding operation at a very slight increase in cost.

Hydroseeding a mix of seed, fertilizer, and mulch can be very effective on areas with difficult access and roughened seedbeds. Improved results, however, can be obtained by applying seed and mulch independently. This two-step approach aids in effectively covering the seed. The slurry approach often deposits seed on top of the mulch or traps it between mulch fibers where it can become fooled into premature germination. The benefits of mulching, including increasing soil moisture, decreasing soil temperatures and holding seed in place, should be weighed against the expense of the mulching operation. Often a roughened seedbed may be the cheapest and most effective treatment for establishing vegetation (Kay 1977).

The use of a 10-20-10 fertilizer was a waste of funds. Western soils in general require no potassium supplement, as they are already high in this plant nutrient. Inclusion of potassium in the fertilizer mix is not necessary. Desert soils are generally low in nitrogen and phosphorous, and for this reason, the addition of a 10-20-0 fertilizer is sufficient in supplementing project soils.

Indian Bend Wash

Site Conditions

Results of a previous study of this project by Conrad and Patten in 1979, indicated that problematic soil conditions exist in several areas along the wash. The soils along the wash were found to be alkaline, with pH values ranging from 8.4-8.9. Of the 32 sites, tested roughly one-third were classified as sodic (soils with percent exchangeable sodium in excess of 15). Sodium, at these levels, creates soil structure problems. Soils are compacted, water infiltration is decreased, and aeration is low. Due to these poor physical conditions, as well as nutrient deficiencies and toxicities, sodic soils often will not support plant life. In addition to sodic soils, five sites along the wash were discovered to have salinity problems, with electrical conductivity in excess of 4 mmhos/cm. This condition leads to nutrient imbalances, ion toxicities and a reduction of available soil moisture (Brady 1974).

Seedbed Preparation

In the preparation of the seedbed along Indian Bend Wash, no action was taken to ameliorate the poor soil conditions. There was also no addition of topsoil or fertilizer. As a result, the final seedbed was, in many places, not suited physically or chemically for seed germination and plant establishment. Furthermore, grading operations left a smooth seedbed. Only the areas along the bike path, where rocks were positioned, were suitable in creating the irregularities that facilitate moisture retention and provide a beneficial seedling habitat.

Plant Species Selection

Seeding rates at Indian Bend Wash are unknown. For this reason, information on recommended seed rates was excluded from this species review. The number of species seeded in this project, necessitates the use of the following table (Table 2) for their review.

Planting Procedure

Seeds were broadcast in the summer of 1977, during a dry period, with no application of mulch. Following broadcasting operations, the area was dragged with a chain to cover the seeds.

TABLE 2.—Review of Seeded Species at Indian Bend Wash.
(N) designates native plants, (NN) nonnative plants.

<u>Atriplex lentiformis</u> (N) Quailbush	Valuable in replanting open areas; Good drainage required; Very drought tolerant shrub; Grown successfully in alkaline and saline soils. (2 & 3).
<u>Chilopsis linearis</u> (N) Desert Willow	Planted in dense stands for erosion control; Does best in deep, loose gravelly soils with good drainage; Most often found in wash areas; Heavy summer water required (1 & 4).
<u>Chrysothamnus nauseosus</u> (N)* Rubber rabbit brush	Is easily established on harsh sites; An aggressive pioneer with vigorous seedlings; Deep roots provide soil stabilization; Many subspecies with varying tolerances for alkaline and saline conditions; Exercise care in selection of suitable subspecies. (1)
<u>Encelia farinosa</u> (N) Brittle bush	Is easily established from seed in light gravelly soils; Drought tolerant shrub; Does best with 10-12" rain annually; Not noted for tolerance to alkaline or saline conditions. (3)
<u>Eragrostis lehmanniana</u> (NN) Lehman's Lovegrass	Is established easily; Good drought tolerance; Used successfully by Corps at Dreamy Draw; Not noted for tolerance to alkaline or saline conditions. (6)
<u>Isomeris arborea</u> (N) Bladder pod	Grows best in sandy soil along washes; Alkaline tolerant shrub. (5)
<u>Oryzopsis hymenoides</u> (N) Indian Ricegrass	Cool season perennial bunchgrass: Difficult to establish due to low germination and high seed dormancy; Grows on sandy infertile soils with as little as 5-7" of rain annually; Scarification with H ₂ SO ₄ may increase germination - reports vary; Very drought tolerant, and fairly tolerant of saline conditions; Should be used in mixes only; Paloma is recommended variety. (1)
<u>Pennisetum villosum</u> (NN) Fountain grass	Is commonly established by planting from containers; Fairly drought tolerant and with run off waters will do well in areas of 6-12" rain annually; Dormant in winter, fire hazard can result; Widely used ornamental in Michigan, Texas, California and Arizona. (3)

*This species is widespread, several Arizona varieties occur.

TABLE 2 (continued)

Plantago insularis (N)
and lanceolata (NN)
Indian wheat

Easily established annuals; Often used for quick color in seeding operations;
Erosion control limited due to small root system; Drought tolerant;
Tolerance to salinity varies with ecotype. (5)

REFERENCES

1. Long, S. G. 1981
2. Shreve and Wiggins 1964
3. Duffield and Jones 1981
4. Elias 1980
5. Kearney and Peebles 1960
6. Jordon 1981

Sampling Methods

To enable use of a previous report on plant establishment in Indian Bend Wash (compiled for the Corps by Conrad and Patten in 1979) the sampling methods utilized in the study were repeated with a reduction in sample size. In the original study, five transects were placed across the wash with five sampling sites along each transect (Fig. 1). In this study, the five transects were reduced to two. The five sampling sites along each transect line were again utilized. Two permanent stakes had been installed by Conrad and Patten in 1979 40 m apart at each of the five sampling sites along the transects. These were located, when possible, and utilized so that current vegetation could be compared to past observations. Daubenmire's canopy-coverage technique was used with the 2 dm x 5 dm plot frame placed at 1 m intervals between the permanent stakes. The percent cover of species within the plot frame was recorded. From these data, mean cover values per species and percent frequency of these species were obtained.

To sample shrubs larger than 30 cm tall, three 4 m x 8 m quadrats were positioned along each 40 m line. Within each quadrat, number and percent cover for each species were recorded. These data were used to generate mean densities per m and mean percent cover for large shrubs.

Results of Vegetation Sampling

The results of vegetation sampling for Indian Bend Wash are presented in Tables 3 and 4. Results from August 1982 sampling are compared with results from sampling completed in March 1979. The 1979 data were taken from a paper by Conrad and Patten (1979). As previously stated in this report, none of the seeded species, with the exception of Atriplex lentiformis, have become established at Indian Bend Wash. This species, along with Salsola kali (Tumbleweed) made up the majority of the vegetation in 1979. Since 1979, as the data in Table 3 reflects the frequency of Salsola has greatly diminished. While the reduction of tumbleweed in the wash area is desirable, this decrease in frequency and cover is demonstrative of a general trend toward declining vegetation. Examination of Table 4 shows that while mean percent cover for large A. lentiformis has in general increased, it is coupled with an alarming decrease in densities of young A. lentiformis (less than 30 cm tall). Furthermore, migration of A. lentiformis into areas where it did not occur previously is accompanied in many cases by decreases in mean densities and even abandonment by Atriplex in other areas. Annual occurrence, cover and density

Figure 1. Sampling transects and study sites along Indian Bend Wash. X designates transects studied in 1979 and in 1982. Figure taken from Conrad and Patten, 1979.

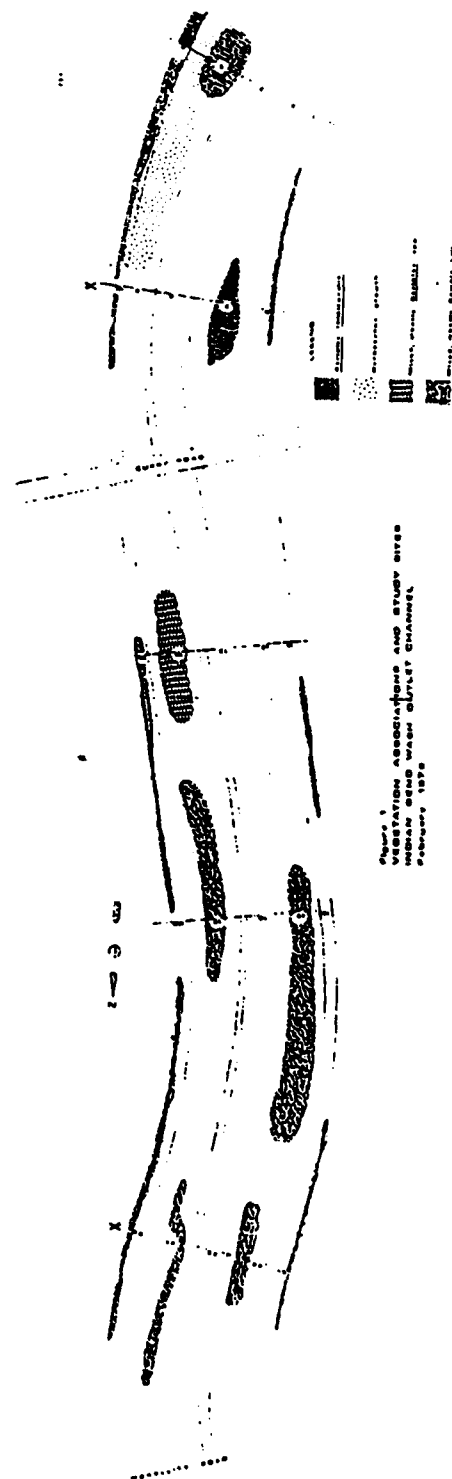


TABLE 1. Mean frequency (0/0), and mean cover (0/0) for species smaller than 30 cm found in Indian Bend Wash in March 1979 and in August 1982. March 1979 figures used are from a report to the Army Corps by Conrad and Patten (1979). (C) designates cover, (F) frequency.

Plot No.	6				7				8				9			
	79		82		79		82		79		82		79		82	
SPECIES	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Annual Grasses																
<u>Aristida adscensionis</u>	-	-	-	-	-	-	-	-	-	-	1.05	22.50	-	-	1.00	7.50
<u>Bromus arizonicus</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Phalaris caroliniana</u>	-	-	-	-	-	-	-	-	-	-	0.08	2.50	-	-	-	-
<u>Schismus barbatus</u>	1.31	25.00	4.75	25.00	12.30	67.50	6.90	53.00	6.13	97.50	2.20	37.50	21.70	100.00	23.70	97.50
Others too decomposed for identification	-	-	-	-	-	-	-	-	-	-	0.13	25.00	-	-	0.32	7.50
Other Annuals	-	-	-	-	-	-	-	-	0.75	17.50	1.90	35.00	-	-	0.05	2.50
<u>Atriplex elegans</u>	0.50	7.50	-	-	8.56	45.00	-	-	5.75	75.00	-	-	8.31	97.50	-	-
<u>Monolepis nuttalliana</u>	0.94	37.50	-	-	26.90	47.50	-	-	0.44	17.50	0.26	20.00	-	-	-	-
<u>Salsola kali</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perennials Seeded:																
<u>Atriplex lentiformis</u>	0.06	2.50	-	-	4.19	25.00	-	-	6.13	40.00	-	-	0.25	10.00	0.18	2.50
Nonseeded:																
<u>Baccharis sarothroides</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Stephanomeria</u> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL COVER*	2.93		4.75		69.10		6.90		3.09		5.95		34.07		25.30	

* Total cover is sum of individual mean cover. NOTE: Not all species found in 1979 are listed. Total cover for 1979 includes those species not listed.

TABLE 3 (Cont inued)

Plot No.	10						21						22						23					
	79		82		79		82		79		82		79		82		79		82		79		82	
SPECIES	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Annual Grasses																								
<u>Aristida adscensionis</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Bromus arizonicus</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Phalaris caroliniana</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Schismus barbatus</u>	17.00	100.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others too decomposed for identification	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Annuals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Atropis elegans</u>	7.31	60.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Monolepis nuttalliana</u>	2.88	27.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Salsola kali</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perennials	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seeded:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Atropis lentiformis</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nonseeded:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Baccharis sarothroides</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Stephanomeria</u> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL COVER*	38.00		0		0.13				4.90		7.29		2.38		26.09									

*Total cover is sum of individual mean cover. NOTE: Not all species found in 1979 are listed. Total cover for 1979 includes those species not listed.

TABLE 3 (Continued)

Plot No.	24				25			
	79		82		79		82	
SPECIES	C	F	C	F	C	F	C	F
Annual Grasses								
<u>Aristida adscensionis</u>	-	-	-	-	-	-	-	-
<u>Bromus arizonicus</u>	-	-	-	-	-	-	-	-
<u>Phalaris caroliniana</u>	-	-	-	-	-	-	-	-
<u>Schismus barbatus</u>	1.31	27.50	-	-	2.06	70.00	0.50	5.00
Others too decomposed for identification								
Other Annuals								
<u>Atriplex elegans</u>	-	-	-	-	0.50	0.20	0.13	2.50
<u>Honolepis nuttalliana</u>	0.50	20.00	-	-	0.36	15.00	-	-
<u>Salsole kali</u>	0.63	25.00	-	-	-	-	-	-
Perennials								
Seeded:								
<u>Atriplex lentiformis</u>	7.31	50.00	-	-	0.44	5.00	0.25	5.00
Nonseeded:								
<u>Baccharis sarothroides</u>	-	-	-	-	-	-	-	-
<u>Stephanomeria sp.</u>	-	-	-	-	-	-	-	-
TOTAL COVER*	64.11		0		4.19		0.88	

* Total cover is sum of individual mean cover. NOTE: Not all species found in 1979 are listed. Total cover for includes those species not listed.

TABLE 4.— Comparison of 1979 and 1982 data for mean density (no./m²) and percent cover of Atriplex lentiformis and A. elegans in Indian Bend Wash Outlet Channel for ten of the sites studies by Conrad and Patten (1979).

SITE	<u>Atriplex lentiformis</u> < 30 cm. tall			<u>Atriplex lentiformis</u> > 30 cm. tall			<u>A. elegans</u>		
	mean density	mean cover		mean density	mean cover		density	mean cover	
	1979	1982		1979	1982		1979	1982	
6	0.02	-	1.00	-	0.14	22.30	-	-	-
7	0.61	-	11.66	-	0.79	40.00	-	-	-
8	-	-	-	-	-	-	16.8	1.90	-
9	0.34	0.25	3.00	0.18	0.19	30.00	0.01	1.00	0.05
10	1.16	-	5.33	-	0.26	11.66	0.04	2.00	-
21	-	-	-	-	0.05	9.70	-	-	-
22	0.52	0.25	2.50	0.125	0.17	5.70	1.75	0.075	-
23	-	-	-	-	-	-	1.38	12.33	-
24	0.83	-	4.33	-	0.30	8.60	-	-	-
25	0.09	0.05	1.00	0.25	0.06	1.66	0.01	2.00	1.25

decreased from March 1979 to August 1982. This decrease for annual species is naturally related to the differing seasons in which sampling was conducted. For perennial species, however, these decreases are cause for concern. In the sampled areas most perennial species appearing both in 1979 and in 1982 sampling showed reduction in cover, number and frequency (Table 3).

From qualitative observation in Indian Bend Wash there is no evidence that vegetation is moving into barren areas along the wash. This demonstrates an inability of these areas as they now exist to provide suitable growth habitats. After five years, these areas remain barren and erosion is rampant.

Conclusions

The seedbeds at Indian Bend Wash were not prepared properly. No steps were taken to ameliorate poor soil conditions. In addition to soil chemistry problems, the smooth, compact seedbed offered little opportunity for microhabitat development. The existence of microenvironments within a seedbed is crucial to establishing vegetation. In those places where surface irregularities occurred, along the stone and soil areas lining the bike path, Atriplex lentiformis stands are best established. The roughened seedbed serves as a catchment for in-blown species as well. It is recommended that mitigation measures be taken to adjust problem soils and that a roughened seedbed be prepared for future projects. At Indian Bend Wash, a simple harrowing operation to roughen the compacted soils would increase the probability of in-blown species germinating and establishing in barren areas.

Of the eleven species selected for use in Indian Bend Wash, only five exhibit tolerances for the alkaline soils found there. Of the five, Oryzopsis has the lowest tolerance to saline conditions. This lower tolerance, coupled with the extreme difficulty in establishment of this species can account for its failure in the wash. Both Plantago species, it should be noted, have a varied tolerance for alkalinity and this tolerance is dependent on ecotype. For this reason, it is quite probable that ecotypic varieties with low alkaline tolerances were planted and failed to establish. Chrysothamnus nauseosus, like the Plantago species, also exhibits varied alkaline tolerances. Many subspecies of this species exist and without careful selection of the type to be sown, failure in alkaline areas is to expected. Isomeris arborea, a native of alkaline washes should have done well in Indian Bend Wash. It is possible that a lack of seed cover, or the heavy flooding in 1977, could have contributed to the failure of this species to establish.

Another factor in the failure of the alkaline tolerant species (in addition to poor seedbed preparation) could have been the saline nature of much of the soil. Tolerant of both high pH and salty conditions, Atriplex lentiformis established readily along the wash. Following the initial establishment of this species, individuals of Atriplex aged, matured and died, often with minimal reproduction. This process has lead to a decline in stand densities. When seedlings fail, stand failure will follow. It is believed that improving microhabitat potential through soil roughening practices leads to an increase in seedling number and vigor. If this increase can be accomplished, the decline of Atriplex stands might reverse and result in their expansion.

The planting procedure utilized to broadcast the seed followed by chain dragging the area, can often provide adequate seed dispersal and cover on non-compacted seedbeds. On compacted seedbeds, however, seeds are inadequately covered by dragging operations. Seeds planted in this manner often lie exposed to both predator and environment. Without sufficient cover, these seeds will fail to germinate. It is recommended that broadcast seeding on compact, smooth seedbeds be avoided (Jordon 1981).

Cave Buttes Dam

Site Conditions

Two areas within the Cave Buttes Dam project were examined, Borrow Pits 1 and 2. Only Borrow Pit 2 was seeded and the inclusion of Borrow Pit 1 in this report is to show a comparison between plant establishment on seeded and non-seeded areas.

A mean annual rainfall of 11.8" at Cave Buttes was reported in a previous paper presented to the Corps by Patten and Barstad in 1979. This rainfall, slightly higher than average for the surrounding desert, is notable and probably due to the proximity of mountains. The soils in this area are typically shallow and poorly developed. Patten and Barstad (1979) reported soil characteristics for the project area. For the purposes of this review, the findings of Patten and Barstad from Borrow Pits 1 and 2 will be used. Soils in these areas are sandy loams, and alkaline in nature. In Borrow Pit 2, which was seeded by the Corps in 1979, pH values range from 7.8 - 8.7. Neither site can be classified as sodic, since percent exchangeable sodium values were less than 15. However, the reported values are somewhat higher than in the surrounding desert. Salinity at these sites is

nonproblematic. The electrical conductivities ranging from 0.9 -3.0 mmhos/cm indicate soils hospitable to all but salt sensitive species and fall within normal conditions where salt tolerant plants grow.

Seedbed Preparation

Borrow Pit 2 was disked to relieve compaction. Contours were left, creating small hills and depressions within the borrow pit. No topsoil, mulch or other amendments were added. The final seedbed was rough and undulating, with a large number of microhabitats.

Plant Species Selection

Three Atriplex (Saltbush) species were seeded in Borrow Pit #2. This genus is, in general, drought tolerant and tolerant of both saline and alkaline soil conditions. Pure live seeding rates for the three Atriplex species, and for Baccharis (Desert broom) the fourth seeded species, were not specified (See Appendix).

Atriplex canescens (four wing salt bush) is a long-lived perennial shrub that is easily established from seed. Once established, four wing saltbush is fairly cold hardy; however, young plants are frost sensitive. A deep rooting system provides erosion control and on mine tailings this saltbush has competed successfully to eliminate Salsola (Tumbleweed) (Hassell 1977). This species was seeded at a rate of 4 lbs./acre. Recommended rates are 2-4 lbs.PLS/acre of dewinged seed for broadcast seeding (Jordon 1981, Nord 1977, Duffield and Jones 1981).

Atriplex polycarpa (Desert saltbush) is not as cold tolerant as the four wing saltbush; however, it is more drought tolerant. This species can survive on as little as 4-5" of annual precipitation distributed mainly during the winter months. It thrives in deep well-drained soils at elevations up to 5,000 ft. Desert saltbush is easily established on harsh sites and is most often used in conjunction with other Atriplex species (Nord 1977, Hassell 1977). Atriplex polycarpa was seeded at the rate of 6 lbs./acre.

Atriplex lentiformis (Quailbush) is tolerant of extreme heat and cold. Quailbush does best with additional water from runoff or where deep roots can penetrate to a shallow water table. It establishes easily from seed and is considered more aesthetically pleasing than other saltbushes (Hassell 1977, Duffield and Jones 1981). Atriplex lentiformis was seeded at a rate of 12 lbs./acre.

Baccharis sarothroides (Desert broom) is an aggressive pioneer on disturbed sites. It has been widely used for revegetation and for erosion control on stream banks. Desert broom adapts to a variety of soil types and is moderately salt tolerant. Occasional irrigation may be required for establishment of this species in areas with less than 10" of annual rainfall. Seed from Baccharis is difficult to collect and clean but has a high germination rate. This high rate of germination promotes rapid spreading of this plant once established (Duffield and Jones 1981). Baccharis sarothroides was seeded at the rate of 2 lbs./acre.

Planting Procedures

In December 1979, Borrow Pit 2 was broadcast seeded by hand, at the rate of 24 lbs./acre. Following broadcasting, the area was harrowed to cover the seed. No mulch was applied.

Sampling Methods

Two areas within the Cave Buttes project were sampled for vegetation; Borrow Pit 1 and Borrow Pit 2. Borrow Pit 2, located just off Jomax Road, was sampled using three transect lines with 10 4 m x 8 m quadrats along each line. The positioning of these transects; along a depression, on a ridge, and in the level area near the base of dike 2, allowed comparison of a number of habitats within Borrow Pit 2. Within each 4 m x 8 m quadrat shrubs taller than 30 cm were counted and percent cover by species was estimated. In each corner of the 4 m x 8 m quadrat a smaller "nested" quadrat 0.5 m x 2 m was positioned; species smaller than 30 cm were counted, and cover estimates for these species were recorded. From these data, mean percent cover and frequency for large and small species were obtained.

Borrow Pit 1 is populated by small herbaceous growth. For this reason, the 2 dm X 5 dm quadrat size was used. Three transects were positioned along a ridge, a depression and in a level area. A total of 40 quadrats were sampled along these transects. Occurrence and numbers were noted for each species. Mean frequency and density data were compiled from this sampling.

Results of Vegetation Sampling

Results of vegetation sampling within the nonseeded Borrow Pit 1 are presented in Table 5. The list of species occurring in this area consists almost entirely of annual plants. No shrubs or other species taller than 30 cm were sampled in Borrow Pit 1 and a qualitative observation revealed a relatively flat topography.

It was initially thought that the variable topography existing in Borrow Pit 2 would tend to separate the species environmentally. No major vegetational distribution patterns, as shown in Tables 6 and 7, have resulted from the varying topography. There is however a general trend toward larger plants (as indicated by high percent cover) in the depression areas.

Of the seeded species, Atriplex polycarpa appears to be highest in percent frequency and mean cover for most of the sites. Although present in small amounts in the flat and ridge areas (amounts too small to be detected by this sampling method), Baccharis has established well in the depressions where its moisture requirements are met.

Conclusion

A good seedbed was prepared in Borrow Pit 2. It was left roughened and the varying topography of small hills and depressions created a variety of microhabitats for collecting seed and moisture. Vegetative sampling results demonstrate that the occurrence of small hills, depressions and level areas has not notably segregated species. The failure of these findings to demonstrate differential plant establishment on these areas means that microtopography rather than macrotopography is the key to the rapid establishment of plant species.

Soils tests showed that no soil amendments were required and the alkaline soils were dealt with by selection of alkaline tolerant species. A good species mix was designated; all species used were tolerant of drought and high pH. Seeding dates were optimum, falling within the season of heaviest rainfall. Broadcasting by hand distributed the seeds well and adequate seed cover was provided by harrowing. Success in seedbed preparation, species selection, and planting procedures all contributed to a successful seeding revegetation project. The resulting vegetation is well established and the presence of young plants, presumably reproduction from the seeded species,

TABLE 5.— Mean frequency (o/o) and mean density (no./m²) for plant species found in Borrow Pit #1 at Cave Buttes Dam in August 1982.

<u>SPECIES</u>	<u>FLAT</u>		<u>RIDGE</u>		<u>DEPRESSION</u>	
	Freq.	Density	Freq.	Density	Freq.	Density
Grasses						
<u>Bromus rubens</u>	50.00	1.00				
<u>Cynodon dactylon</u>					15.40	1.54
<u>Phalaris caroliniana</u>					54.00	6.20
<u>Schismus barbatus</u>	100.00	111.40	69.20	53.90	7.70	1.54
<u>Sitanion Hystrix</u>			46.20	4.62	7.70	0.77
Annuals						
<u>Amsinckia intermedia</u>	14.30	1.43	23.10	2.31		
<u>Datura metaloides</u>					15.40	1.54
<u>Eriogonum sp.</u>						
<u>Erodium cicutarium</u>	14.30	1.43	30.80	5.38	7.70	0.77
<u>Marrubium vulgare</u>			23.10	2.31	15.40	1.54
<u>Petunia parriflora</u>					7.70	0.77
<u>Plantago sp.</u>	14.30	4.30	15.40	1.54		
<u>Polanisia trachysperma</u>	35.70	5.70	76.90	12.30		
<u>Polygonium argyrocoleon</u>					7.70	0.77
<u>Proboscidea parriflora</u>			15.40	1.54		
<u>Rumex triangularis</u>					7.70	0.77
<u>Salsola kali</u>	93.00	36.40	15.40	1.54		
<u>Sphaeralcea sp.</u>					7.70	0.77
<u>Solanum elaeagnifolium</u>					7.70	0.77
<u>Sonchus sp.</u>					7.70	0.77
<u>Verbesina encelioides</u>			7.70	0.77		
<u>Xanthium saccharatum</u>					15.40	1.54
Perennials						
<u>Prosopis juliflora</u>					15.40	1.54

TABLE 6.— Mean frequency (%), mean total cover (%), and mean density (no/m²) for plants smaller than 30 cm found in Borrow Pit Number 2 at Cave Buttes Dam, August 1982.

SPECIES	LEVEL			RIDGE			DEPRESSION		
	Freq.	Cover	Density	Freq.	Cover	Density	Freq.	Cover	Density
Seeded:									
<u>Atriplex canescens</u>	50.00	1.68	1.40	47.50	0.38	0.68	25.00	0.94	0.30
<u>A. lentiformis</u>	12.50	0.40	0.15	7.50	0.06	0.08	17.50	0.62	0.48
<u>A. polycarpa</u>	60.00	2.68	3.28	72.50	3.65	1.63	55.00	4.73	1.35
<u>Baccharis sarothroides</u>	-	-	-	-	-	-	17.50	0.70	2.25
Annual:									
<u>Bromus rubens</u>	5.00	0.04	0.08	5.00	0.04	0.05	2.50	0.05	0.05
<u>Erodium cicutarium</u>	-	-	-	50.00	1.61	4.65	35.00	0.81	2.68
<u>Plantago sp.</u>	-	-	-	2.50	0.05	0.25	-	-	-
<u>Salsola kali</u>	12.50	0.29	0.20	7.50	0.08	0.75	17.50	0.41	0.55
<u>Schismus barbarus</u>	100.00	8.40	54.30	57.80	1.31	6.50	97.50	5.08	40.40
Perennial:									
<u>Eriogonum sp.</u>	10.00	0.25	0.13	22.50	0.38	5.80	25.00	0.71	1.65
<u>Sphaeralcea sp.</u>	-	-	-	2.50	0.08	0.10	-	-	-
TOTAL COVER *		13.80			9.37			13.64	

*Σ of estimated total cover for each nested Quadrat/total # Quadrats.

TABLE 7.— Mean frequency (o/o), mean cover (o/o), and mean density (no./m²) for plants taller than 30 cm found in Borrow Pit Number 1 at Cave Buttes Dam, August 1982.

SPECIES	FLAT			RIDGE			DEPRESSION		
	Freq.	Cover	Density	Freq.	Cover	Density	Freq.	Cover	Density
Seeded:									
<u>Atriplex canescens</u>	100.00	10.10	0.23	100.00	3.90	0.12	100.00	4.00	0.08
<u>A. lentiformis</u>	100.00	12.16	0.39	60.00	1.60	0.03	100.00	6.90	0.18
<u>A. polycarpa</u>	100.00	9.99	0.21	100.00	6.20	0.21	90.00	6.00	0.17
<u>Baccharis sarothroides</u>	-	-	-	-	-	-	10.00	0.30	0.13
Nonseeded:									
Annual									
<u>Salsola kali</u>	-	-	-	-	-	-	20.00	0.40	0.01
Perennial									
<u>Stephanomeria exugia</u>	-	-	-	-	-	-	10.00	0.05	0.01
TOTAL COVER*		37.70			18.00			25.90	

* Σ of estimated total cover for each Quadrat/total # Quadrats.

demonstrates a healthy vegetative stand. In addition, the migration of nonseeded species into the area indicates the successional return of this area to a community of plants similar to that found in the surrounding desert.

In the nonseeded borrow pit, the succession process is developing more slowly. The area, after approximately four years, has a relatively high percentage of annual plants. The return to a stable community of shrubs and other perennials, as well as annuals, is proceeding at a much slower rate in Borrow Pit 1 than in Borrow Pit 2. This difference is to be expected, as established vegetation modifies soil conditions and creates favorable microhabitats under the plant canopy for seed catchment and germination. Additionally, the relatively even soil surface of Borrow Pit #1 fails to provide conditions as favorable for plant establishment as the rough surfaces in Borrow Pit 2. It is recommended that in the future, all nonseeded areas be roughened prior to abandonment to facilitate successional development.

General Conclusions

Site Conditions

Prior to planning a revegetation project, climate and soil conditions must be examined. A review of climate, including temperature extremes and average annual rainfall, is important in selection of suitable plant species. For example, the use of Lolium multiflorum (annual rye) at Dreamy Draw Dam, could have been avoided by considering the intolerance of this species of dry conditions. The seasonal distribution of rainfall is as important as the total average annual precipitation in planning for seeding success. Rainfall in Maricopa County is primarily distributed in two seasons summer and winter, with winter rains being the heaviest (Green and Sellers 1964). It should be noted however, that rainfall is highly variable in Arizona. This variability means that any seeding operation involves a certain risk, as proper seedling establishment requires sufficient rainfall. For this reason, it is crucial to plan seeding dates to coincide with the seasonal distribution of rain. For example, in the Indian Bend Wash project, summer seeding should have been avoided, while December seeding at Cave Buttes Dam contributed to the success of this seeding project.

Careful soil analysis preceeding the revegetation plan can often save money, and prevent seeding failures. An analysis of soils at Indian Bend Wash could have alerted

planning personnel to the problematic soil conditions. Based on this information, an informed decision on the mitigation of these soil conditions could have been made. As no tests were made, soil conditions were unknown, and the seeding operation failed.

Seedbed Preparation

Proper seedbed preparation, based on the findings of soil analyses could have saved the seeding project at Indian Bend Wash. Given a similar situation, a cost analysis on correcting problematic soils is recommended. In extreme localities, where establishment of vegetation is crucial, the addition of soil amendments to the seedbed is suggested. If the expense of required amounts of ameliorating amendments is prohibitive, burying the offensive soil materials with nonproblematic soils is an alternative. These practices are costly and should be avoided when soil conditions allow vegetative establishment by tolerant species.

When topsoil additions are used, measures should be taken so that the topsoil is not lost, as was the case at Dreamy Draw Dam. It is recommended that whenever topsoil is used, it should be either lightly tilled into subsoils, or applied to roughened subsoils. These practices promote binding of the topsoil to the underlying soils. Unless soil analyses demonstrates the necessity of topsoiling, its use should be avoided; it is an expensive process. Often it is possible to establish good vegetation covers on properly amended and roughened subsoils. Grading these amended subsoils will often yield a more desirable seedbed than topsoiling (Wright, Perry and Blaser 1978).

Whenever it is necessary to vegetate a small critical area, for instance, a highly erodable slope, the high costs of topsoiling, fertilizer and other amendments can be justified. A carefully prepared seedbed can lead to seedling establishment on these critical areas.

In addition to amending the seedbed, seedbed preparation often requires mechanical manipulation. A general rule of thumb for correcting compacted seedbeds is to till or rip the area when the bulk density exceeds 1.65 gms/cc. The tilling operation is complete when the resulting surface is very irregular, with small depressions, rises and large stones when possible. "The detrimental practice of constructing seedbeds with smooth, hard surfaces gives a false impression of 'finished grading' and a job well done, but vegetation often fails. Rough surfaces, with the rocks left in place, give an ugly appearance to the novice, but encourage water infiltration and speed up the establishment of vegetation, as well as decrease the rate of water flow" (Wright, Perry and

Blaser 1978). A study by Wright, Perry and Blaser (1978) showed that roughened surfaces, whether topsoil or subsoil, increased soil moisture, decreased soil temperatures, improved seed germination, plant densities and protective cover. In addition, a four-fold improvement of vegetative cover for roughened subsoil was reported over smooth areas. The seeding results at Cave Buttes Dam, where undulations and a ripped soil surface in Borrow Pit 2 created favorable seed habitats, reflect these findings.

Plant Species Selection

Recommendations for future projects must include selection of species, based not only on climatic and aesthetic suitability, but on tolerance to soil conditions. Species selected without regard to tolerances for problematic soil conditions will most likely fail. This occurred at Indian Bend Wash. Furthermore, the Indian Bend Wash project demonstrates that when a species is selected for its adaptation to a soil condition, care should be taken to insure that the most favorable ecotype, variety, or subspecies is used. When these factors are not considered, improper species are seeded and funds are wasted.

Species used successfully on Corps' projects reviewed include Eragrostis Lehmanniana, Atriplex species (A. lentiformis, A. polycarpa, and A. canescens), and Baccharis sarothroides. It is recommended that this list be expanded to include other adapted species for use as site conditions allow. The seeding rates of the previously used species yielded satisfactory results. On future projects, it is recommended that seeding rates be specified as pounds of Pure Live Seed (PLS) per acre. Use of pounds per acre can jeopardize the seeding operation through the use of seed with low germination and purity rates. Recommendations for the number of pure live seeds per unit area and methods for calculating pure live seed are outlined in the Appendix.

Planting Procedures

There exists a misinformed belief that seeds planted in almost any season will remain viable until favorable germination conditions arise. This belief often leads to seeding in inopportune seasons. Gilbert Jordon (1981) argues that "the seedbed is a very poor place to store seeds". While it is true that the seeds of many species may remain dormant until conditions favoring germination occur, seed viability is highly variable among species. Predation by insects and rodents, mortality from disease or premature germination, all act to lower seed viability. Viability is

decreased the longer the seed remains dormant in the soil. Certainly, it is unwise to depend on carry-over seed from last season's seeding operation for the success of a revegetation project. Gilbert Jordon further suggests the following guidelines for seeding times:

"For all seeding of cool season species, the site should receive an average of 3.5 inches of precipitation through November, December, January and February. For late spring seeding, the site should receive an average of 5.0 inches through July, August and September." He recommends against planting warm season species in the fall.

The seeding at Cave Buttes Dam in December, although not strictly recommended, allowed two to three months of rain for seedling development. The Indian Bend Wash project however, was seeded in the summer. The chance of brief summer thunder storms jeopardized seeding success. Seedlings can be fooled into early germination by these storms and face a period of hot, late summer and fall drought prior to winter precipitation. Mid to late fall seeding for Maricopa County is generally recommended, primarily because rain fall is usually heaviest during the winter in this area.

Hydroseeding and broadcasting seed have been effectively used at Dreamy Draw and Cave Buttes dams respectively. Broadcasting on compacted soils, as performed at Indian Bend Wash should be avoided. Hydroseeders with centrifugal pumps should not be used. Results of a study by B.L. Kay (1977) show a dramatic decrease in seed germination for seeds sown with this type of hydroseeder. If use of a centrifugal pump hydroseeder is unavoidable, the following practices can decrease the harmful effects: (1) delivery time (time from placing the seed in water until the tank is empty) should be limited to twenty minutes, (2) the pump system should not be used to sow seed without mulch, and (3) a fiber mulch (500 lbs wood fiber/1500 gal. water) should be used which protects the seed from the destructive pump action. Whenever possible, it is recommended that hydroseeders with a gear pump and paddle agitation be used (Kay 1977).

The use of mulch to cover seed, increase moisture, and decrease temperatures is beneficial. However, no product can improve on covering the seed with soil (Kay 1979). Dragging or harrowing as performed at Cave Buttes Dam, following the seeding operation, can insure proper seed coverage. Broadcasting seed on compacted surfaces, is not recommended; dragging these compacted surfaces to cover the seed, as was done at Indian Bend Wash, has little value. Covering the seed can often be easily accomplished by simply preparing a rough seedbed.

The review of the Dreamy Draw Dam, Indian Bend Wash and Cave Buttes Dam projects should serve to illustrate the importance of seedbed preparation, selection of suitable plant species, and proper seeding procedures in successful revegetation. Future research in these areas is needed and findings should be used to increase success while decreasing wasted funds. In seedbed preparation, the use of modifying subsoils rather than adding expensive topsoil should be investigated. Many different grading machines exist which are especially designed to create roughened seedbeds; their use for Corps' projects is certainly worth examining. The use of seedmixes including grasses, forbs and shrubs would increase diversity and stability in revegetated areas. And finally, lowered revegetation success from seeding in unfavorable seasons should be documented.

Relationship of Past Revegetation Experience to Adobe Dam

Revegetation at Adobe Dam used both seeding and transplanting. Because analyses of other Corps revegetation projects emphasized the reseeding procedures, this discussion will be related to the Adobe Dam revegetation with transplanting discussed in a later task.

Seeding as a revegetation technique has evolved in the Phoenix area from the Dreamy Draw project to the present Adobe Dam project. At Dreamy Draw hydroseeding was used and top soil was applied along with mulch and fertilizer. Because the seed species used were exotic to the area, some surface dressing was essential but use of fertilizer was unnecessary and wasteful.

Seeding at Indian Bend Wash took an opposite extreme from Dreamy Draw. The seed bed was never prepared and seeds were scattered on dry, rock hard soil that was alkaline. No site analyses had been made and seed species selection included only a few species that had a chance of success, specifically Atriplex lentiformis. The Indian Bend Wash revegetation project was a failure and natural revegetation has gradually occurred.

Cave Buttes Dam revegetation took two directions, (1) abandonment of borrow pits to natural revegetation and (2) surface preparation, broadcast seeding and surface dragging. In addition, seed species selection was based on potential alkalinity of the site. Variable topography, dragged soil surface after seeding and good seed species selection have created a successful revegetation project at Cave Buttes Dam. The unseeded borrow pits are slowly but naturally revegetating.

The Adobe Dam project uses a mixture of the procedures used at the other projects. Seed species selection included both species that prefer alkaline soil (e.g., Saltbush-*Atriplex* spp.) and species that are intolerant of alkaline soil (e.g., brittle bush - *Encelia farinosa*). This selection gave a potential for at least partial project success. If soil had been analyzed prior to seed species selection, a greater potential for success could be predicted. Seeds were distributed by hydroseeding and the surface dragged on the dam slope. No fertilizers, mulches or top soils were added. They were not needed because of better than expected quality of the soil and soil surface dragging. On the flat areas south of the dam, the soil was compacted due to construction and thus inhospitable to seeding establishment. Based on a comparison of the seeding procedures, one could predict for the Adobe Dam project, a revegetation success intermediate between that at Indian Bend Wash in Tempe (a failure) and Cave Buttes Dam (a total success).

One issue not already addressed is timing of seeding. Adobe Dam was seeded at an appropriate time, late winter, for the eastern portion of the dam and inappropriate time, spring, for the western portion. Seeding times on the other projects were not available for comparison.

Appendix

Calculation of a pure live seed (PLS) rate involves both germination rate and percent purity

$$\text{PLS} = \% \text{ purity} \times \% \text{ germination}$$

This calculation, allows planning personnel to design reliable seed mixes, and gives a rough idea of expected yields. By stating seeding rates in pounds PLS/acre, the use of inferior quality seed is avoided, as purity and germination vary depending on seed source. To illustrate the calculation of PLS, the following example is presented.

In the Cave Buttes Dam seeding operation, 4 lbs./acre of Atriplex canescens were seeded. To calculate the number of Pure Live Seeds/acre, percent purity and percent germination are required. For example:

$$\% \text{ purity} = 95$$

$$\% \text{ germination} = 80$$

$$95\% \times 80\% = 0.76 \text{ PLS}$$

$$4 \text{ lbs. seeded} \times 0.76 = 3.04 \text{ lbs.}$$

or simply stated for this example, the 4 lbs. of Atriplex canescens seeded only contained 3.04 lbs of pure live seed. If 4 lb PLS was desired:

$$4 \text{ lbs.} / 0.76 = 5.3; 5.3 \text{ lbs. of seed would be required.}$$

It is easy to see from the example given, how stating seeding rates in lbs/acre can often lead to disappointing results.

To determine seeding rates, the following guidelines are presented.

Jordon recommends using approximately 1 million PLS/acre. This rate means that 23 seeds/sq. ft. can be expected to germinate.

For seed mixes, Cook, Hyde and Sims (1974) suggest the following guidelines:

Grasses 6-8 species totalling 20-25 PLS/sq.ft.
Forbs 3-6 species totalling 3-6 PLS/sq.ft.
Shrubs 2-3 species totalling 2-4 PLS/sq.ft.

These rates are for drill seeding and should be doubled for broadcast seeding, and quadrupled for hydroseeding. In critical areas these rates can be increased still further.

GLOSSARY

ANNUALS - Plants that complete their life cycle within one season; in the desert this may be within a few weeks.

BULK DENSITY - The weight of soil (dried) per soil volume, e.g. gm/cc; a higher bulk density often indicates soil compaction.

COVER - The amount, usually percent, of the ground covered by the aerial (sometime basal) parts of the plants observed from a vertical or overhead position.

DENSITY - The number of individuals per unit area.

ECOTYPE - A genetic variation of a species that is adapted to or has tolerances for a specific environment.

FREQUENCY - The percentage occurrence of a species representing commonality of distribution.

HABITAT - The overall environment of the location of one or more plant or animal species.

MICROENVIRONMENT - The environment immediately surrounding a species in contrast to the general environment of the biotic community.

PERENNIALS - Plants that have a life cycle lasting for many years.

QUADRAT - A sampling unit, usually rectangular in shape; a series of quadrats is usually used for sufficient sampling.

SUCCESSION - The process by which plants replace each other in response to environmental changes thus gradually changing the plant community.

TRANSECT - A line or path along which samples are taken to determine vegetational composition.

VIABILITY - The health and vigor level of seeds permitting survivability and potential germination.

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